On the Negative Pricing of WTI Crude Oil Futures

Adrian Fernandez-Perez, Ph.D.
Auckland University of Technology, New Zealand

Ana-Maria Fuertes, Ph.D.
Cass Business School, City, University of London, U.K.

Joëlle Miffre, Ph.D.
Audencia Business School, Nantes, France

The empirical work in this digest article is based on*:*
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3748321

WTI crude oil futures markets experienced the unprecedented phenomenon of negative prices on April 20, 2020. Several energy market pundits attributed the event to the large United States oil exchange-traded fund ("USO") due to the rolling of positions out of the May 2020 contract (CLK20) before the contract's maturity on April 21, 2020. We show empirically that USO flows have not influenced the flat price of WTI futures in general, nor of the CLK20 contract in particular. A blend of macroeconomic/geopolitical conditions, including the sudden demand plunge associated with COVID-19 pandemic-control measures and various supply spikes due to Russia-Saudi Arabia tensions, contributed to a contangoed WTI futures curve that attracted cash-and-carry (C&C) arbitrage, sharply increasing the inventories at Cushing, and feeding into a super-contango, as concerns on storage capacity loomed. That said, a full understanding of the negative WTI price phenomenon of April 20, 2020 requires a formal examination of market microstructure issues on that day, which is a matter for further research.

Introduction

The futures price of the May 2020 delivery futures contract on WTI crude oil (CLK20) swung dramatically from $18.27 (April 17, 2020) to a negative price of -$37.63 (April 20, 2020) – meaning effectively that sellers paid buyers to take crude oil barrels off their hands – and climbed back to $10.01 at maturity (April 21, 2020). This is the first time that a WTI futures contract has experienced negative prices since NYMEX WTI trading began on March 30, 1983. The existence of the United States Oil fund (with ticker symbol USO), one of the main trackers of the WTI crude oil performance, has been controversial and a frequent target of criticism by energy market pundits. In particular, some oil market commentators have implicitly or explicitly stated that the massive USO long futures positions on WTI crude oil and the corresponding rolls as contract maturity approached are to blame for the anomalous negative CLK20 pricing.

This article contributes to the literature on the price behavior of WTI crude oil futures contracts, firstly, by empirically testing the conjecture that USO trading induced the unprecedented negative price. For this purpose, the authors conduct an eclectic set of Granger-causality tests to determine whether USO flows (changes in open interest) have any predictive power for price changes of CLK20. The results indicate that USO flows did not drive the returns of CLK20 which is not surprising upon the recognition that USO had already rolled all of its long positions on CLK20 to more distant contracts as of April 13, 2020 (or seven

This digest article was contributed by Ana-Maria Fuertes, Ph.D., Professor in Finance and Econometrics at Cass Business School, City, University of London (U.K.) and Associate Editor of the GCARD.

days before the CLK20 price crash) and even at the close of April 12, 2020, only a fourth of its long contracts needed yet to be rolled as the process is spread out over four days. The test results suggest more generally that USO flows do not influence the flat price of any WTI futures contracts it has ever traded.

The second contribution of this article is to examine the plausible contributing causes of the pricing of CLK20 in April. The findings suggest that the pricing of WTI futures in April 2020 was influenced by the rampant cash-and-carry (C&C) arbitrage that was catalyzed by a dramatic oversupply of crude oil. In the early months of 2020, the oversupply of crude oil inherited from the last decade (oil "glut") took an adverse turn due to the shattered worldwide demand because of COVID-19 pandemic control measures, together with spikes in supply associated with geopolitical tensions between Russia and Saudi Arabia. The WTI futures market steered into a contango which acted as a strong catalyst for C&C arbitrage. The latter, in turn, sharply increased the Cushing (Oklahoma) inventories and storage costs and fed into a super-contango that attracted further C&C trades. As the maturity of CLK20 became closer, the spiraling dynamics between arbitrage and inventory triggered fears of an eventual tank tops scenario in Cushing. That said, in order to fully understand the reason why the WTI futures contract price could trade at a negative price on the day before contract maturity, one would also formally need to explore a number of technical, market microstructure factors of that day.

Relevance of the Research Question

The research question is important as it relates to the ongoing commodity markets financialization debate. The findings speak to the literature on the financialization of energy futures markets by showing that index traders and long-only asset managers, such as USO, are unlikely to have driven the flat price of crude oil futures away from its fundamental value and thus, they did not alter the outright price formation process (Fattouh *et al*., 2013; Bessembinder *et al*., 2016; Byun, 2017). This suggests that calls for further regulation of speculative participants might be, at this stage, premature since it could, in fact, be detrimental as it may discourage these providers of risk-absorption and liquidity from trading crude oil futures.

The findings also speak to the empirical literature on the theory of storage by bringing indirect evidence that the law of one price implied by the cost-of-carry model does not hold in the presence of storage constraints. In so doing, it complements the analysis of Ederington *et al.* (2020) by focusing on the anomalous negative pricing of CLK20, and by showing that limits in the availability of storage facilities can hinder the execution of C&C riskless arbitrages, which otherwise could provide a bid for the near-month contract. Practical implications include lessons for C&C traders, who need to exert caution during super-contangoed futures markets as storage constraints effectively imply that the C&C strategy can suddenly become quite challenging and thus, highly risky in incurring substantial margin calls during the period of the trade.[1] Likewise, traders and investors not seeking to take physical delivery need to exert caution in rolling their long positions sufficiently ahead of maturity to avoid being caught in dramatic liquidity freeze outs (Bouchouev, 2020; Bouchouev, 2021). Commodity futures markets can sometimes have "nodal liquidity": before entering a commodity futures position, a market participant should understand what flow would be on the other side of the trade to be able to exit at non-distressed levels (Till, 2008).

Data and Methodology

The paper relies on a wide sample of daily settlement prices and open interest (or total outstanding contracts) for all 446 WTI crude oil futures traded from March 30, 1983 to June 29, 2020. For comparison, we also obtain the settlement prices of front and second-nearest maturity futures contracts on Brent crude oil over the available period December 12, 1988 to June 29, 2020.[2] All prices are from Refinitiv Datastream. The investigation also employs daily long USO open interest data on WTI crude oil from October 24, 2008 to June 29, 2020 (as sourced from United States Commodities Fund (USCF) archives.)

The paper also looks at crude oil storage capacity, supply and demand data. Weekly working storage capacities for the U.S. and different Petroleum Administration for Defense Districts (PADDs) – PADD 1 (East Coast), PADD 2 (Midwest which includes Cushing), PADD 3 (Gulf Coast), PADD 4 (Rocky Mountains) and PADD 5 (West Coast) – are obtained from the Energy Information Administration (EIA) website. We also obtain from the EIA website: monthly worldwide crude oil production, as a measure of supply. Finally, we obtain monthly worldwide (and U.S.) crude oil and liquid fuels consumption data, as a proxy for world (and U.S.) demand, from Refinitiv Datastream. The start date of the different datasets is dictated by data availability, and the end date is June 26, 2020 throughout.

To test the hypothesis that USO flows do not influence the outright price of WTI futures contracts generally, the authors estimate a panel regression of the pooled WTI excess returns on their lagged values as well as on lagged values of the changes in USO's open interest,

$$r_t = \alpha_i + \alpha_{tm} + \sum_{j=1}^{P} \beta_j r_{t-j} + \sum_{j=1}^{P} \gamma_j \Delta OI_{t-j} + \varepsilon_t, i = 1, \dots, 148, \; t = 1, \dots, T \qquad (1)$$

where r_t is the WTI excess return from the end of day $t-1$ to the end of day t, ΔOI_t the change in USO's open interest from day $t-1$ end to day t end, α_i are individual fixed effects to account for unobserved heterogeneity across futures contracts, α_{tm} are monthly time effects to account for seasonality in crude oil markets, β_j and $\gamma_j, j = 1, \dots, P$ denote the marginal effects of prior futures returns and USO's flows, respectively, on current returns, *P* is a maximum lag order to capture any serial dependence in daily returns, and ε_t is an error term.

To test the hypothesis that USO trading from March 6, 2020 to April 13, 2020 (i.e., the short period during which USO held long positions on CLK20) did not influence the outright price of CLK20, the authors respecify the above Granger-causality model Equations (1) by introducing a CLK20 dummy variable, D_t, as follows:

$$r_t = \alpha_i + \alpha_{tm} + \left(\sum_{j=1}^{P} \beta_j + \sum_{j=1}^{P} \beta_{D,j} D_t\right) r_{t-j} + \left(\sum_{j=1}^{P} \gamma_j + \sum_{j=1}^{P} \gamma_{D,j} D_t\right) \Delta OI_{t-j} + \varepsilon_t \qquad (2)$$

where D_t is a dummy equal to 1 on days *t* from March 6, 2020 to April 13, 2020 (when USO held open interest on CLK20) and 0 otherwise; the additional parameters $\beta_{D,j}$ and $\gamma_{D,j}$ in these equations capture the specific effects of USO trading on CLK20 prices, over and above the effect of USO trading on all other WTI contracts (as captured by β_j and γ_j).

Results from Granger-causality Tests

The joint hypothesis $H_0: \gamma_1 = \cdots = \gamma_P = 0$ with reference to Equation (1) is not rejected by the Wald test, which is confirmed by individual ($\gamma_j = 0$) tests using *t*-statistics. This suggests that nearly since USO's inception, from October 24, 2008 to June 29, 2020, its flows have not caused WTI futures price changes. USO is a price taker, not a price maker.

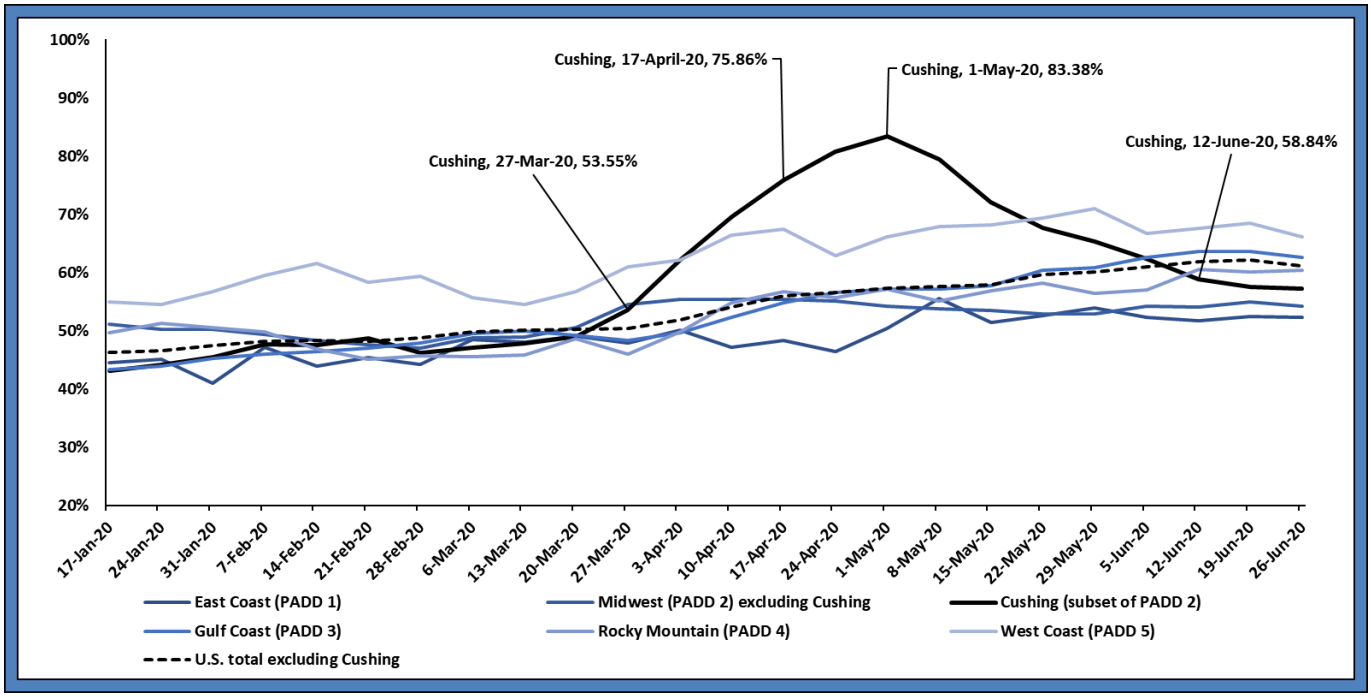
The joint restrictions $H_0: \gamma_{D,1} = \cdots = \gamma_{D,P} = 0$ in Equation (2) are not rejected either by similar tests. These findings in conjunction with those from the prior tests based on Equation (1), and the fact that USO did not hold any CLK20 contracts already 7 business days before its maturity, suggest that overall USO's flows did not drive the anomalous price changes of this contract. Overall, the evidence suggests that USO is unlikely to have induced the negative pricing of CLK20 on April 20, 2020, one day before contract expiry.

Robustness tests as regards the model specification used to conduct the Granger-causality tests (variants of Equations (1) and (2) with different maximum lag orders P, various controls, and considering the lag distributed effect of spreads) do not challenge the above findings.

Other Findings

Through the following graph the authors show that while there is an upward trend in the storage utilization rate in all hubs, there is a dramatic jump in the Cushing utilization rate during April 2020.

Figure 1
Crude Oil Storage Capacity Utilization in Different PADDs



The graph clearly illustrates the fact that unlike the other hubs, Cushing is the physical settlement point for WTI futures and hence, its inventory dynamics reflect more than operational factors.

The sudden slowdown of crude oil demand (driven by COVID-19 control measures) alongside the Russia versus Saudi Arabia tensions that triggered supply spikes are likely to have played a role in turning the early 2020 modest contango in the WTI futures market into a super-contango in late March 2020. This super-contango would have attracted C&C arbitrage in WTI crude oil and would have naturally induced the sharp increase in the Cushing storage utilization rate. Brent futures also entered a super-contango state, but not as much as WTI, and the Brent futures price did not enter negative territory. Even though rampant C&C arbitrage might have also occurred using Brent futures contracts, a key contrast with WTI futures contracts is that they can be cash-settled.

In support of the claim that the contango of the WTI crude oil futures market attracted C&C arbitrage which, in turn, raised inventory levels at Cushing, and induced a super-contango, the authors measure the correlation between the futures spread at week t (measured as the difference between the front and second-nearest futures prices) and the Cushing inventory at $t + 2$. From January 17, 2020 to June 19, 2020, the correlation is a significant -0.86; the more negative the futures spread at time t (deeper contango), the more C&C arbitrage trades, and, consequently, the Cushing inventories rise 2 weeks ahead when the delivery of the expired long position takes place. Similarly, the correlations between spread at t and inventory at $t + j$, $j = \{1,3,4\}$ weeks are significant and negative at -0.77, -0.82 and -0.70, respectively. This is consistent with Cushing inventory levels being strongly linked to arbitrage activity; arbitrageurs contract storage capacity ahead to exploit distortions between futures prices at different maturities. In addition, the authors provide data-based illustrative examples of how the C&C arbitrage might have induced the sharp inventory build-up at Cushing (as Figure 1 shows) during April 2020.

Regarding the typical behavior of market participants, like USO other long-only (or long-short strategy) asset managers are unlikely, in the main, to have held CLK20 on April 20, 2020 since they have no interest in taking or making delivery of the physical asset at maturity and thus, they typically roll their positions to more distant contracts a few weeks before front-end contracts mature. One documented exception, though, is in Bouchouev (2020), who discusses the Bank of China's retail investment product: Yuan You Bao ("Crude Oil Treasure"), which "still held positions for thousands of retail investors" at the start of April 20, 2020.

Hedge funds that engage in pure speculation (*e.g.*, CTAs) are unlikely to have held long CLK20 on April 20, 2020 for two reasons. First, since speculators do not want to take physical delivery which would require additional costs (*e.g.*, storage costs, insurance) they usually roll their contracts a few weeks prior to maturity to avoid exposure to illiquidity-driven price fluctuations. Second, various trading signals in March (roll yield, momentum, basis-momentum, relative basis) hinted towards a poor forthcoming performance of CLK20 and thus, rational speculators ought to have then taken short (as opposed to long) positions in that contract. Finally, long hedgers are also unlikely to have been largely caught in the predicament of holding CLK20 on April 20, 2020 because, first, they typically close their positions weeks before maturity to avoid illiquidity issues and second, as the WTI market entered a phase of deep contango, long hedgers would have had an incentive to decrease their long hedge rather than increase it. The Commodity Futures Trading Commission's (CFTC's) Interim Staff Report (2020) confirms this; traders in the

"Product/Merchant" group held below average long positions on CLK20; namely, only 14.7% of the open interest on April 20, 2020 was associated with long hedgers, which is considerably less than the trailing average of 52.5% on the penultimate day of trading of contracts active in the previous 12-months.

The CFTC's Interim Staff Report (2020) reveals that the share of long open interest held by "non-reportable" (small) traders and "other reportables" as higher than average for the penultimate day of trading. CFTC (2021) defines the "other reportables" category as excluding physical market participants, swap dealers, or managed money. Because the non-reportable and "other reportables" participants would likely not have had access to storage with which to resolve their long futures positions by taking physical delivery of oil, these participants would have been at risk to an "unexpected shortfall in buy orders," as phrased by Pirrong (2020c). The next section provides a discussion on how a liquidity freeze out could have occurred, which is based on considering who would typically be the natural buyers of crude oil futures contracts so close to contract maturity.

Liquidity Freeze Outs

How might have a liquidity freeze out occurred on April 20, 2020? Such a freeze out could occur, for example, due to "strategic behavior" on the part of commercials holding short futures positions (against physical holdings), who could observe the historically high open interest coming into the contract's maturity and could have chosen to delay buying in (short) hedges, an activity which would have normally provided a bid for exiting non-commercial long futures contract holders. Another risk for non-commercial traders holding futures contracts near to a contract's maturity (during a time of limited storage capacity) is that those participants who may still have had access to very limited storage could have delayed putting on new trades, given the amount of open interest remaining at the time, which would enable them to enter into a storage play at exceptional levels and thereby not go long the front-month futures contract except at extremely favorable levels for a C&C trade. Further, other physical traders may not have been "motivated to buy … futures [contracts] and take delivery of physical barrels … [when there was] high uncertainty about the availability of storage capacity," as noted by Bouchouev (2021). An aggravating factor on April 20, 2020 could have been a strategy employed by proprietary trading firms of going long the near-month contract at the Trade-at-Settlement (TAS) price earlier in the day, followed by aggressively closing out these positions with sell orders near the close. And they did so at a time when "buyers [who could or would] take physical delivery of WTI crude had all but disappeared", as discussed in Vaughan *et al.* (2020); such a strategy, it should be noted, would have led to substantial profits for these intraday trading participants. Bouchouev (2021) discusses the further signaling that would have happened when there was an emergence of unfilled TAS orders on April 20, 2020, indicating an imbalance of longs attempting to liquidate positions, putting such participants in quite a vulnerable state. At any rate, as the events of April 20, 2020 arguably showed, liquidity provision is not automatic during the day *before* the futures contract matures, if participants who otherwise have previously provided a bid for crude oil futures contracts near to the contract's maturity do not do so, either due to exerting "market power" or due to limits on effective storage capacity. In addition to the Bouchouev references, the consideration of this collection of factors is informed by the discussions in Pirrong, (2020a), Pirrong (2020), and Pirrong (2020c).[3]

Conclusions

Using a comprehensive dataset of WTI crude oil futures prices and USO open interest, the authors conduct formal empirical tests of the contention that United States Oil fund (USO), the largest WTI crude oil exchange traded fund, induced the catastrophic negative pricing of the WTI crude oil futures contract for May delivery (CLK20). The analysis shows that USO flows do not Granger-cause the outright prices of WTI futures contracts in general, nor of the CLK20 contract in particular.

Further analysis suggests that the contango associated with a disastrous blend of macroeconomic and geopolitical conditions, such as a rising surplus triggered by geopolitical tensions and a demand obliterated by the COVID-19 lockdowns, attracted a splurge of cash-and-carry (C&C) arbitrage trades that increased the Cushing inventories with a negative feedback effect on the intensity of the contango and C&C arbitrage opportunities.

In uncovering exactly why crude oil prices could have become negative on April 20, 2020, one needs to understand the precise interplay of the technical factors on that day, some of which we have touched upon, but which is a topic for future formal research.

Endnotes

1 Hecht (2015) describes how cash-and-carry trades work in the commodity markets, including how these trades have "virtually no risk other than margin flow via mark-to-market risk for the period" of the trade.

2 Unlike the WTI crude oil futures contract that can only be physically settled, the Brent crude oil futures is a deliverable contract based on an Exchange of Futures for Physical delivery with an option to cash settle (ICE Futures Europe, 2021).

3 For completeness, we should note that the Pirrong references include additional insights on the kinds of market manipulations that can potentially occur, especially during times of limited storage, based on past historical examples.

References

Bessembinder, H., Carrion, A., Tuttle, L. and K. Venkataraman, 2016, "Liquidity, Resiliency and Market Quality around Predictable Trades: Theory and Evidence," *Journal of Financial Economics*, Vol. 121, No. 1, July, pp. 142-166.

Bouchouev, I., 2020, "Negative Oil Prices Put Spotlight on Investors," *Risk.net*, April 30, 2020.
Accessed via website: https://www.risk.net/investing/7536946/negative-oil-prices-put-spotlight-on-investors on April 30, 2020. [Dr. Bouchouev is a member of the *GCARD*'s Editorial Advisory Board.]

Bouchouev, I., 2021, "A Stylized Model of the Oil Squeeze," Courant Institute of Mathematical Sciences, New York University and Pentathlon Investments, January 30.
Access via website: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3781158 on March 2, 2021.

Byun, S. J., 2017, "Speculation in Commodity Futures Markets, Inventories and the Price of Crude Oil," *Energy Journal*, Vol. 38, No. 5, September, pp. 93-113.

Commodity Futures Trading Commission, 2020, "Interim Staff Report: Trading in NYMEX WTI Crude Oil Futures Leading up to, on, and around April 20, 2020," November 23, 2020.
Accessed via website:
https://www.cftc.gov/media/5296/InterimStaffReportNYMEX_WTICrudeOil/download on March 3, 2021.

Commodity Futures Trading Commission, 2021, "Disaggregated Explanatory Notes."
Accessed via website:
https://www.cftc.gov/MarketReports/CommitmentsofTraders/DisaggregatedExplanatoryNotes/index.htm on March 3, 2021.

Ederington, L., Fernando, C., Holland, K., Lee, T. and S. Linn, 2020, "Dynamics of Arbitrage," *Journal of Financial and Quantitative Analysis,* pp. 1-31, published online: April 13, 2020. [Dr. Lee is a member of the *GCARD*'s Editorial Advisory Board.]

Fattouh, B., Kilian, L. and L. Mahadeva, 2013, "The Role of Speculation in Oil Markets: What Have We Learned So Far?", *Energy Journal,* Vol. 34, No. 3, pp. 7-33. [Dr. Kilian is a member of the JPMCC's Research Council.]

Hecht, A., 2015, "How Do Cash and Carry Trades Work? An Example in Oil, Applicable to Other Raw Materials," *Seeking Alpha*, April 28.
Accessed via website: https://seekingalpha.com/article/3103436-how-do-cash-and-carry-trades-work-an-example-in-oil-applicable-to-other-raw-materials on February 14, 2021. [Hecht has served as a Subject Matter Expert for the JPMCC's Professional Education Program.]

ICE Futures Europe, 2021, "Brent Futures Contract."
Accessed via website: https://www.theice.com/products/219/Brent-Crude-Futures on February 14, 2021.

Pirrong, C., 2020a, *Streetwise Professor*, April 20.
Accessed via website: https://streetwiseprofessor.com/wti-wtf/ on February 14, 2021. [Dr. Pirrong is a member of the JPMCC's Research Council.]

Pirrong, C., 2020b, *Streetwise Professor*, April 21.
Accessed via website: https://streetwiseprofessor.com/wti-wtf-part-ii-of-how-many/ on February 14, 2021.

Pirrong, C., 2020c, *Streetwise Professor*, April 30.
Accessed via website: https://streetwiseprofessor.com/wti-wtf-part-3-did-clk20-get-tas-ed/ on February 14, 2021.

Till, H., 2008, "Case Studies and Risk Management in Commodity Derivatives Trading," in H. Geman (ed) Risk Management in Commodity Markets, Chichester (U.K.): John Wiley & Sons Ltd., pp. 255-291. [Till is a member of the JPMCC's Research Council.]

Vaughan, L., Chellel, K. and B. Bain, 2020, "London Traders Hit $500 Million Jackpot When Oil Went Negative," *Bloomberg News*, August 4.
Accessed via website: https://www.bloomberg.com/news/articles/2020-08-04/oil-s-plunge-below-zero-was-500-million-jackpot-for-a-few-london-traders on August 4, 2020.

Keywords

WTI crude oil, negative price, theory of storage, contango, cash and carry arbitrage.